



RESEARCH DEPARTMENT

REPORT

**Medium-distance overland tropospheric
propagation measurements at u.h.f.**

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MEDIUM-DISTANCE OVERLAND TROPOSPHERIC PROPAGATION MEASUREMENTS AT U.H.F.

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(RA-35)

MEDIUM-DISTANCE OVERLAND TROPOSPHERIC PROPAGATION MEASUREMENTS AT U.H.F.

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MEDIUM-DISTANCE OVERLAND TROPOSPHERIC PROPAGATION MEASUREMENTS AT U.H.F.

SUMMARY

This report gives the results of a series of long-term tropospheric propagation measurements carried out at u.h.f. over a number of overland transmission paths of lengths ranging from 60 km to 150 km. These measurements, which supplement the data available for frequency planning, are compared with values estimated by two prediction methods. Comparisons of measurements over similar path lengths indicate that the range of fading of the received signal is dependent upon the nature of the receiving location.

1. INTRODUCTION

Information is required regarding the magnitude and duration of occurrence of signals propagated over long distances in order to operate common channel u.h.f. transmitters with the minimum amount of mutual interference.

Long-distance propagation tests have been made by the BBC with transmissions in Bands IV¹ and V² as part of the BBC's contribution to the CCIR Study Programme on tropospheric wave propagation at distances well beyond the horizon, and the results have been incorporated in CCIR curves.³ Only three of the transmission paths investigated were less than 170 km in length. However, with the development of the u.h.f. transmitter network in the United Kingdom the need will arise for many co-channel stations to be sited less than this distance apart.* It was therefore necessary to carry out a further series of tests to supplement the information available regarding the fading range of signals received over path lengths up to approximately 150 km. This report covers these further measurements. A subsidiary series of measurements, concurrent with the main programme, investigated the relationship between range of fading and the type of receiving location.

2. TRANSMISSION PATHS

The u.h.f. transmissions used were the sound channels radiated on Channel 33 (573.25 MHz) from Crystal Palace, (received at six sites) and on Channel 40 (629.25 MHz) from Sutton Coldfield (received at two sites). Transmitting and receiving site details are given in Tables 1 and 2,

The statistical distribution of interfering sources (with respect to distance) is analysed in Appendix I. This analysis emphasises the importance of overland transmission path lengths less than 180 km.

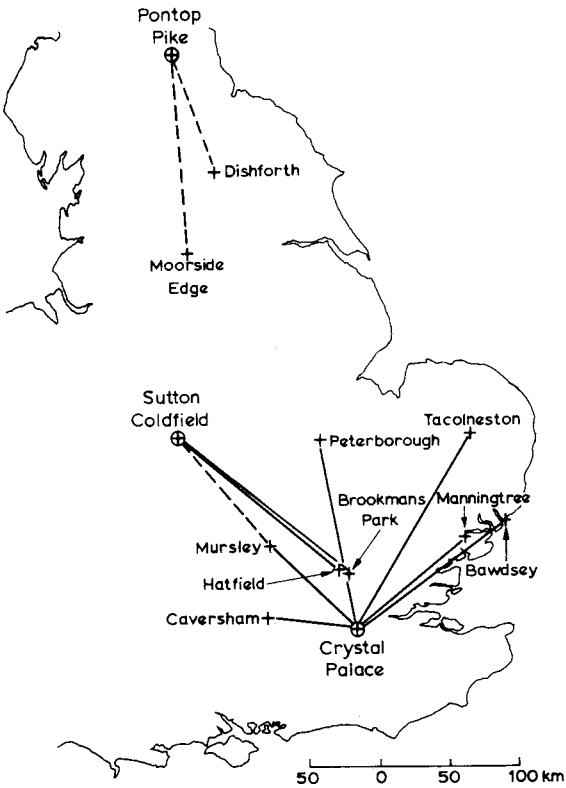


Fig. 1 - Geographical distribution of transmitting and receiving sites

- ⊕ Transmitting sites + Receiving sites
- Transmission paths for new measurements
- - - Transmission paths for previous measurements

and the transmission paths are shown in Fig. 1. For completeness, details of those transmission paths less than 170 km in length, which were investigated in earlier tests^{1,2}, are also tabulated and shown in Fig. 1. Profiles of the various paths are shown in Fig. 2.

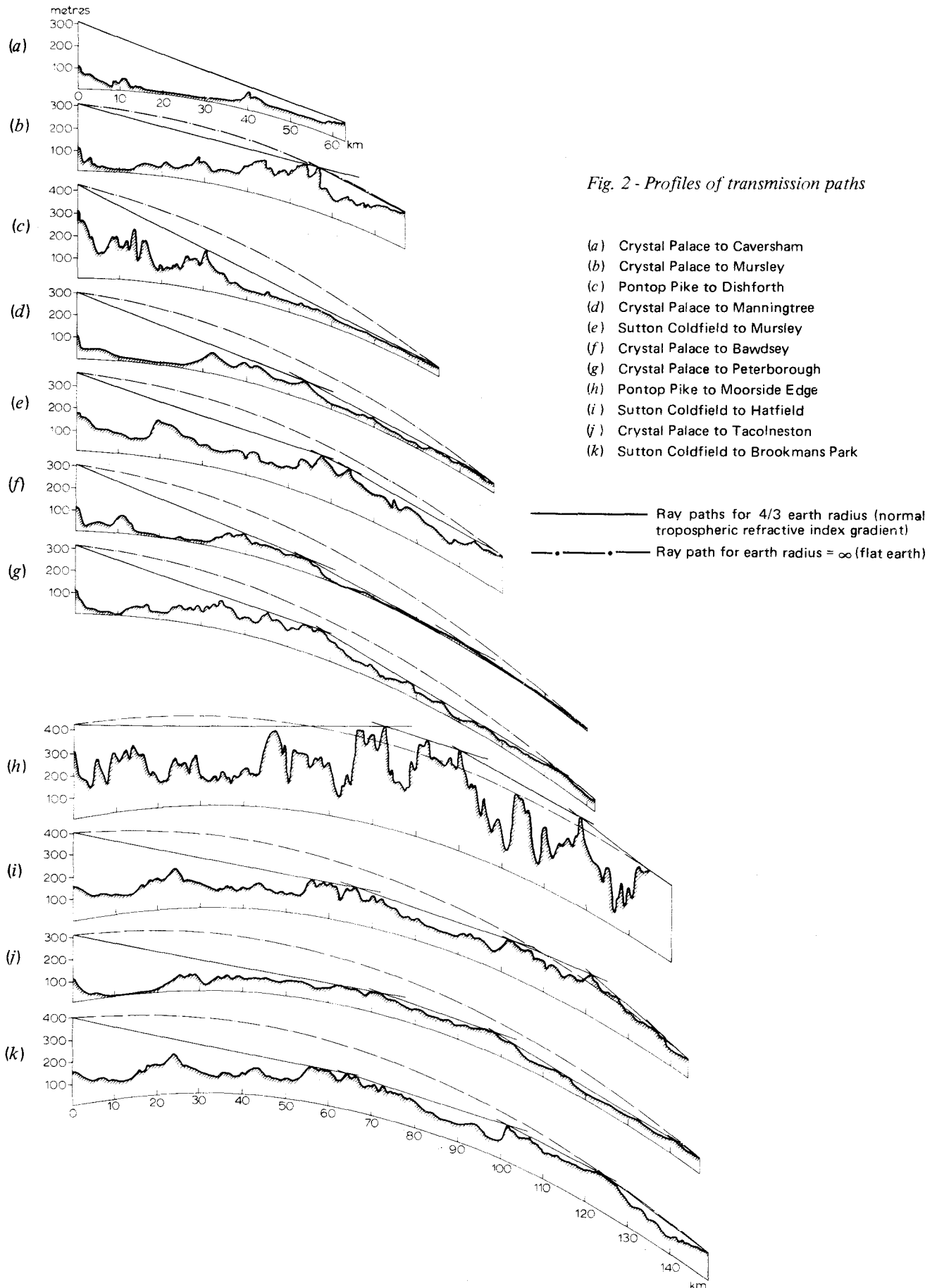


TABLE 1
Transmitting Sites

Station	Freq. MHz	Period of Measurement	Max. e.r.p. kW	Site Height a.m.s.l.		Aerial Height a.g.l.		Lat.	Long
				m	ft	m	ft		
Crystal Palace	573.25	March 1965 to July 1967	100	110	362	194	636	51°25' N	00°04' W
Sutton Coldfield	629.25	Sept. 1966 to Sept. 1967	200	169	555	225	740	52°36' N	01°50' W
Sutton Coldfield	495	July 1955 to July 1956	0.4	169	555	181	594	52°36' N	01°50' W
Pontop Pike	774	June 1959 to Nov. 1960	0.78	305	1000	122	400	54°52' N	01°46' W

All transmissions radiated with horizontal polarization

TABLE 2
Receiving Sites

Receiving Site	Transmitter	E.R.P. toward Rx. Site (kW)	Path Length (km)	Site Height a.m.s.l.		Rx. Aerial Height a.g.l. m	Latitude	Longitude	Bearing from Tx. °E.T.N.
				m	ft				
Caversham	Crystal Palace	65	63	82	260	11	51°28'52" N	00°57'23" W	276°
Mursley	Crystal Palace	65	77	158	500	9	51°57'12" N	00°48'05" W	320°
Dishforth	Pontop Pike	0.78	85	34	112	12	53°38'01" N	01°53'35" W	184°
Manningtree	Crystal Palace	65	98	36	110	9	51°55'25" N	01°05'20" E	55°
Mursley	Sutton Coldfield	0.4	100	158	500	9	51°57'12" N	00°48'05" W	135°
Bawdsey	Crystal Palace	65	120	5	16	13	51°59'30" N	01°25'00" E	58°
Peterborough	Crystal Palace	65	122	60	184	9	52°30'26" N	00°20'30" W	351°
Moorside Edge	Pontop Pike	0.75	140	339	1110	12	53°38'01" N	01°53'35" W	184°
Hatfield	Sutton Coldfield	200	144	76	233	10	37°44'55" N	00°14'20" W	130°
Tacolneston	Crystal Palace	50	147	75	210	9	52°51'05" N	01°08'28" E	34°
Brookmans Park	Sutton Coldfield	200	149	128	420	12	51°43'46" N	00°10'38" W	130°

3. RECEIVING EQUIPMENT

The receivers used for the latest series of measurements, which were described in a previous Research Department Report,⁴ are transistorized crystal-controlled units having nominal bandwidths of 60 kHz. Receiver outputs were recorded at Caversham, Mursley, Manningtree and Bawdsey on recording millimeter charts. At the other receiving sites digital coding equipment^{5,6} was used in addition to the pen recorders, and the analysis of the results was derived from the punched tape output of this equipment.

4. RESULTS

4.1. Analysis

The digital coding equipment used at Hatfield, Brookmans Park, Peterborough and Tacolneston sampled the

received signal level once a minute, this level being recorded on the punched tape in the form of a five digit binary code. These tapes, and the recorder charts used at the other sites, were analysed to determine the length of time during which signal levels exceeded various values of field strength. These time durations, expressed as percentages of the overall valid recording time, were then plotted against field strength in decibels relative to $1\mu\text{V/m}$ [dB($\mu\text{V/m}$)] for an effective radiated power (e.r.p.) of 1 kW.

4.2. Variations of Received Field Strength with Time

The results of the measurements made at each of the sites receiving the Crystal Palace transmission are shown in Fig. 3(a), and of those sites receiving Sutton Coldfield in Fig. 3(b). The results of the three previous measurements over this range of path length are reproduced in Fig. 3(c). Tabulated results of field strength exceeded for specified time percentages are given in Table 3.

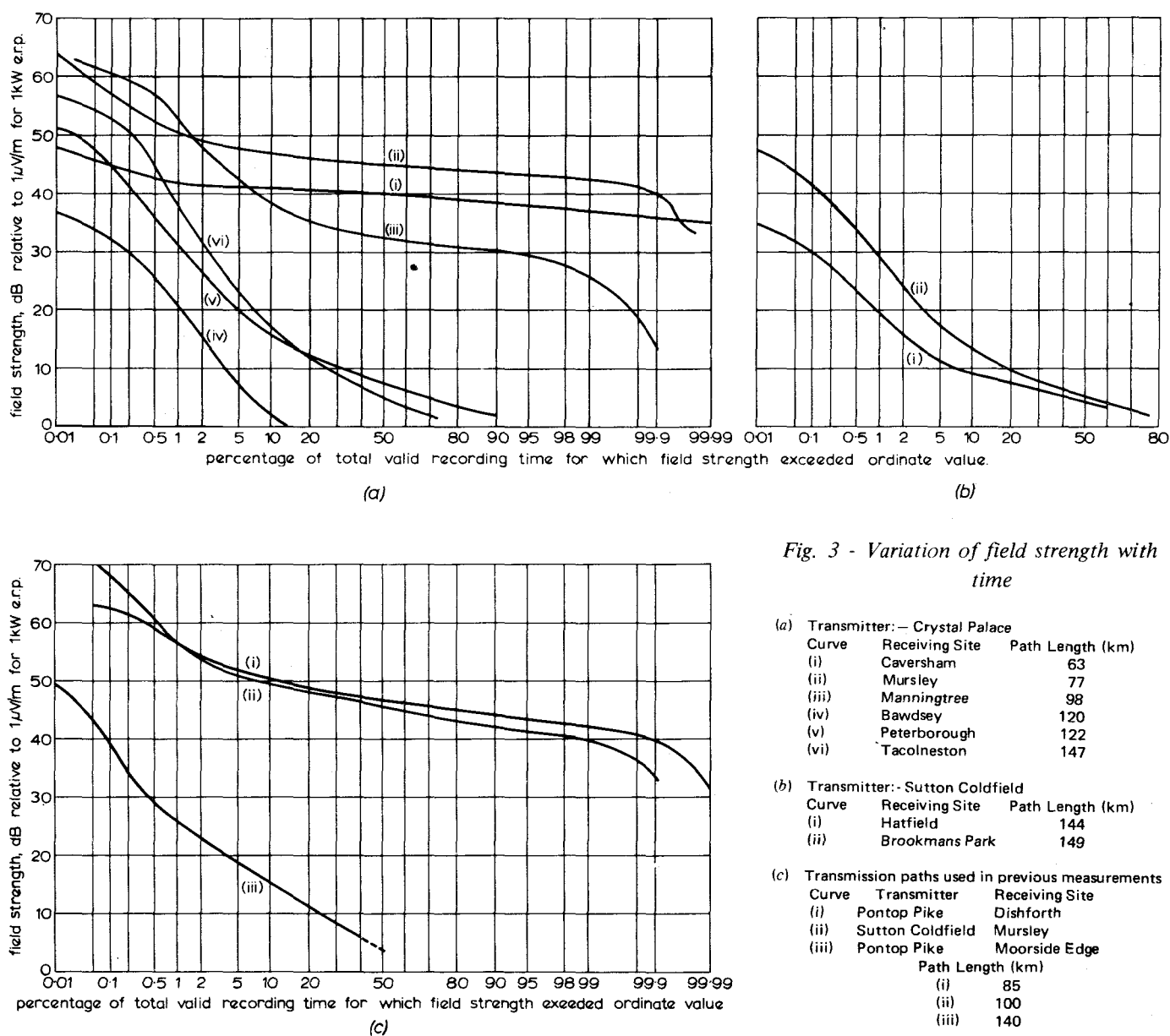


TABLE 3

Results of Measurements

Transmitter	Receiving Site	Path Length (km)	Freq. MHz	Field strength exceeded for specified percentage of valid recording time [dB(μ V/m) for 1 kW e.r.p.]					Free space field strength dB(μ V/m) for 1 kW e.r.p.
				0.1%	1%	5%	10%	50%	
Crystal Palace	Caversham	63	573.25	45.0	41.5	41.0	40.5	39.5	70.9
Crystal Palace	Mursley	77	573.25	57.0	50.5	47.5	47.0	45.0	69.2
Pontop Pike	Dishforth	85	774	62.5	56.5	52.0	50.0	46.5	68
Crystal Palace	Manningtree	98	573.25	60.5	53.0	42.0	38.5	32.5	67.1
Sutton Coldfield	Mursley	100	495	68.0	56.5	51.0	49.5	45.0	67
Crystal Palace	Bawdsey	120	573.25	32.0	21.0	7.5	2.0	—	65.3
Crystal Palace	Peterborough	122	573.25	44.5	31.0	20.0	15.5	7.5	65.1
Pontop Pike	Moorside Edge	140	774	38.5	27.0	18.0	15.0	4.5*	64.1
Sutton Coldfield	Hatfield	144	629.25	30.0	19.5	11.0	9.0	4.0	63.9
Crystal Palace	Tacolneston	147	573.25	52.5	38.0	23.5	17.0	5.0	63.6
Sutton Coldfield	Brookmans Park	149	629.25	41.0	29.0	17.5	13.5	5.0	63.4

* Extrapolated Value

4.3. Standardization of Individual Results

An examination of the results in Table 3, which are arranged in order of increasing distance, shows a poor degree of correlation between path length and received field strength. For example, the lowest values were received over a path length of 120 km, and virtually the highest values over a length of 100 km. It is therefore obvious that over the range of distance represented in this Table the path length is in itself of secondary importance in determining the field strength at a particular receiving location. The other important factors are:— (i) the effective transmitting aerial height, (ii) the nature of the intervening terrain, (iii) the type of receiving location. These factors will be discussed individually.

- (i) The concept adopted by the CCIR in specifying effective transmitting aerial heights is that of height above mean terrain (h.a.m.t.), the mean terrain height being defined as the average height of terrain between 3 km and 15 km from the transmitter. With the exception of the path Pontop Pike to Moorside Edge, for which h.a.m.t. is 240 m, the effective heights for all the other paths are within the range 255 to 300 m. Consequently little error will be introduced by assuming the h.a.m.t. of the transmitting aerial to be approximately 275 m for all paths.
- (ii) The nature of the terrain over any transmission path is of obvious importance in that it will determine the magnitude of the diffraction losses. Field

strengths estimated from the CCIR curves of Recommendation 370-1 take account of terrain roughness by means of an 'attenuation correction factor' which is expressed in terms of a parameter Δh . This parameter represents the difference in terrain heights exceeded for 10% and 90% of the distance along the propagation path between 10 km and 50 km from the transmitter (see Fig. 4(a)). The correction factor curves (reproduced from Rec. 370-1) are shown in Fig. 4(b).

- (iii) In any area the field strength received by tropospheric wave propagation will vary with both time and receiving location. Account of this location variation is taken, at u.h.f., by the CCIR in the form of a correction factor reproduced in Fig. 4(c), which is applied to the 50% location value for any other value of percentage receiving location. It has long been realized that this correction factor is one of the least satisfactory features of the CCIR field strength estimation method since it requires a subjective estimate to be made with regard to the 'goodness' of every individual receiving site. In previous propagation experiments carried out by the BBC the practice has been to determine the 'site variation factor' (s.v.f.) correction to be applied to the results obtained at each receiving location in order to relate these sites to those representative of '50%' locations. Where possible this s.v.f. correction has been established by measurements made at a number of randomly

chosen locations within about 10 km of the particular receiving location used for the long term recordings. However, in view of the factors later discussed in Section 7 it appears that any s.v.f. correction may only be applicable to the particular propagation conditions occurring at the time of the measurement. Obviously the effort involved in attempting to obtain s.v.f. corrections for all types of propagation condition at the required large number of locations would be very considerable. For this reason, in this latest series of measurements the location corrections are estimated on the basis of a method used by the BBC in co-channel interference calculations.⁷ The correction factor obtained by this method is expressed as a function of the horizon elevation (up to a maximum distance of 15 km) measured from the receiving aerial on the bearing of the transmitter. The empirical curve relating correction (in decibels) to horizon angle, which was derived from an analysis of measurements at some 450 receiving locations within the service areas of u.h.f. transmitters is reproduced in Fig. 5. The corrections applicable to the various receiving sites have the effect of normalizing the measurements to those for a site having the horizon elevation 0.35° above the plane of the receiving aerial, the analysis of the original 450 samples having shown this angle to be representative of 50% locations. Where trees form an obstruction in the near vicinity of the receiving point as at Caversham, Bawdsey, and Peterborough, a further correction factor is required. This was obtained by measurements at unobstructed but otherwise comparable locations in proximity to these sites.

4.4. Duration of Measurements

Any regular diurnal or seasonal trends in propagation characteristics will produce a resultant variation in field strength probabilities throughout the day and throughout the year. Such trends are discussed in a previous report.⁸ In order to minimize the effects of seasonal variations in measured results it is desirable that these should be obtained over periods comprising an integral number of years. Of the results discussed in this paper all but four resulted from measurement periods of one or two years duration. Of these other four results, two (receiving terminals at Caversham and Dishforth) exhibited a very small amount of signal variation in any month and it was reasonable to assume that seasonal trends could be ignored. Results derived from the reception of the Crystal Palace transmission at Peterborough (26 months) and at Tacolneston (21 months) were 'weighted' in a manner designed to compensate for any seasonal trends. It was however found that the effect of this weighting was negligible for both transmission paths.

5. COMPARISON BETWEEN MEASUREMENTS AND CCIR FIELD-STRENGTH/DISTANCE CURVES

In Table 4 are given the appropriate correction factors for terrain roughness and receiving location as discussed in the previous section; also tabulated are the resultant

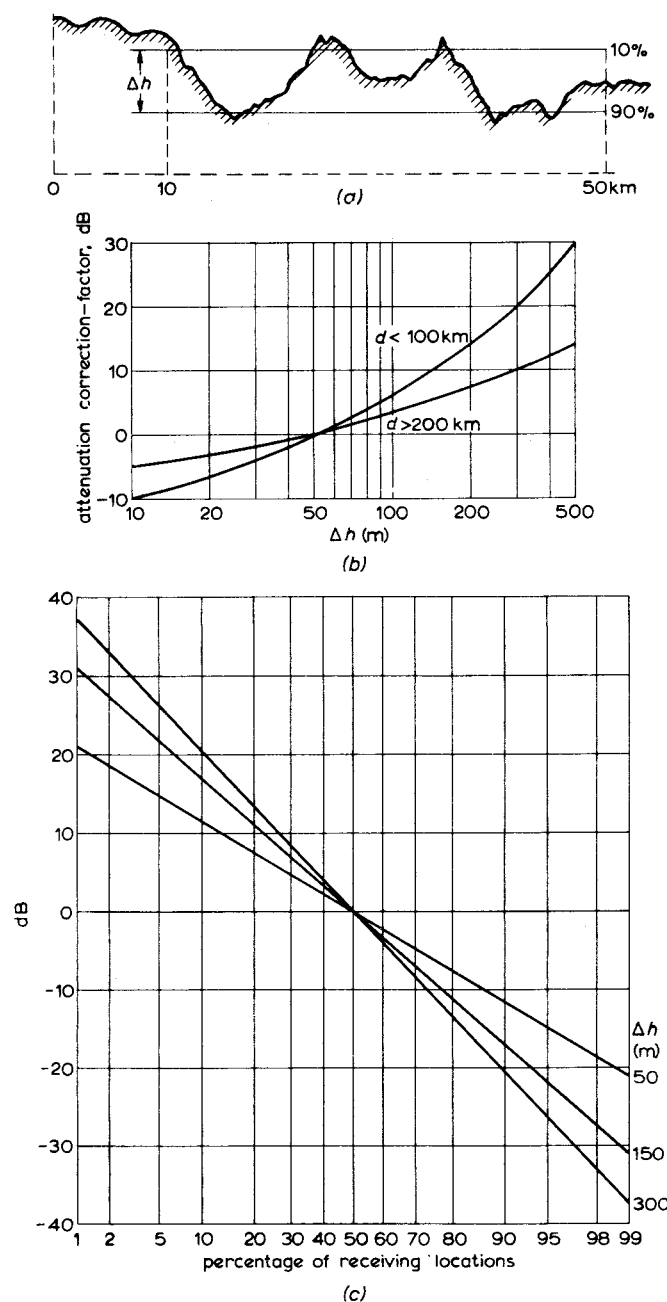


Fig. 4 - CCIR correction factor curves using Δh parameter

- (a) Definitions of the parameter Δh
- (b) Attenuation correction-factor as a factor of Δh for frequencies 450-1000 MHz (Bands IV and V). (Parameter d represents the distance from transmitter.)
- (c) Ratio (dB) of the field strength for a given percentage of receiving locations to the field strength for 50% of receiving locations. (Frequency 450-1000 MHz, Bands IV and V.)

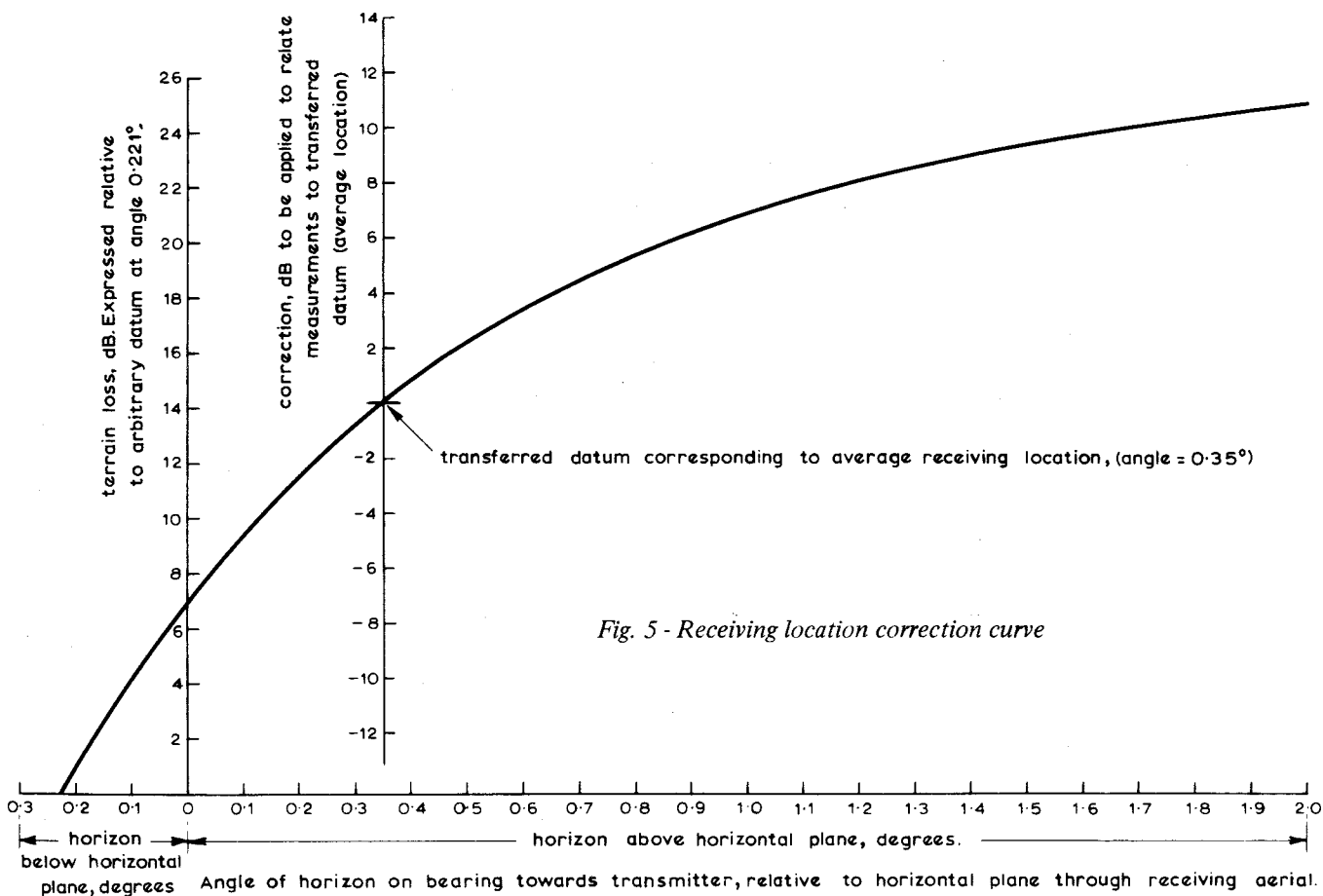
normalized field strengths exceeded for specified time percentages, derived from the values in Table 3. It may be noted that for the three transmission paths investigated in earlier tests the s.v.f. corrections were measured and these measurements are in good agreement with the empirical estimates. Fig. 6 shows the comparison between the normalized results of Table 4 and the CCIR curves for 1%, 10%, and 50% time and effective transmitting aerial height of 275 m above mean terrain.

TABLE 4

Results of Measurements, Modified to Standard Conditions Represented by CCIR Curves
for 275 m h.a.m.t. and Δh of 50 m

x Measured s.v.f. Correction -13 dB
† Measured s.v.f. Correction -10 dB
* Measured s.v.f. Correction -1 dB

Transmission Path	Correction for terrain		Correction for receiving location		Field strength exceeded for specified % of valid recording time, modified to standard conditions dB(μ V/m) for 1 kW e.r.p.		
	Δh (m)	dB from Fig. 4(b)	for angle of Elevation	for local Obstacles	1%	10%	50%
Crystal Palace to Caversham	50	0	-12	16.5	46.0	45.0	44.0
Crystal Palace to Mursley	120	+7	-11	0	46.5	43.0	41.0
Pontop Pike to Dishforth	130	+9	-9 [†]	0 [†]	56.5	50.0	46.5
Crystal Palace to Manningtree	65	+2	-9	0	46.0	31.5	25.5
Sutton Coldfield to Mursley	80	+4	-13 ^x	0 ^x	47.5	40.5	36.0
Crystal Palace to Bawdsey	65	+2	-6	+17	34.0	15.0	—
Crystal Palace to Peterborough	70	+2	-5	+10.5	38.5	22.0	15.0
Pontop Pike to Moorside Edge	165	+9	-2 [*]	0 [*]	34.0	22.0	11.5
Sutton Coldfield to Hatfield	65	+2	0	0	21.5	11.0	6.0
Crystal Palace to Tacolneston	65	+2	-10	0	30.0	9.0	-3.0
Sutton Coldfield to Brookmans Park	65	+2	-8	0	23.0	7.5	-1.0



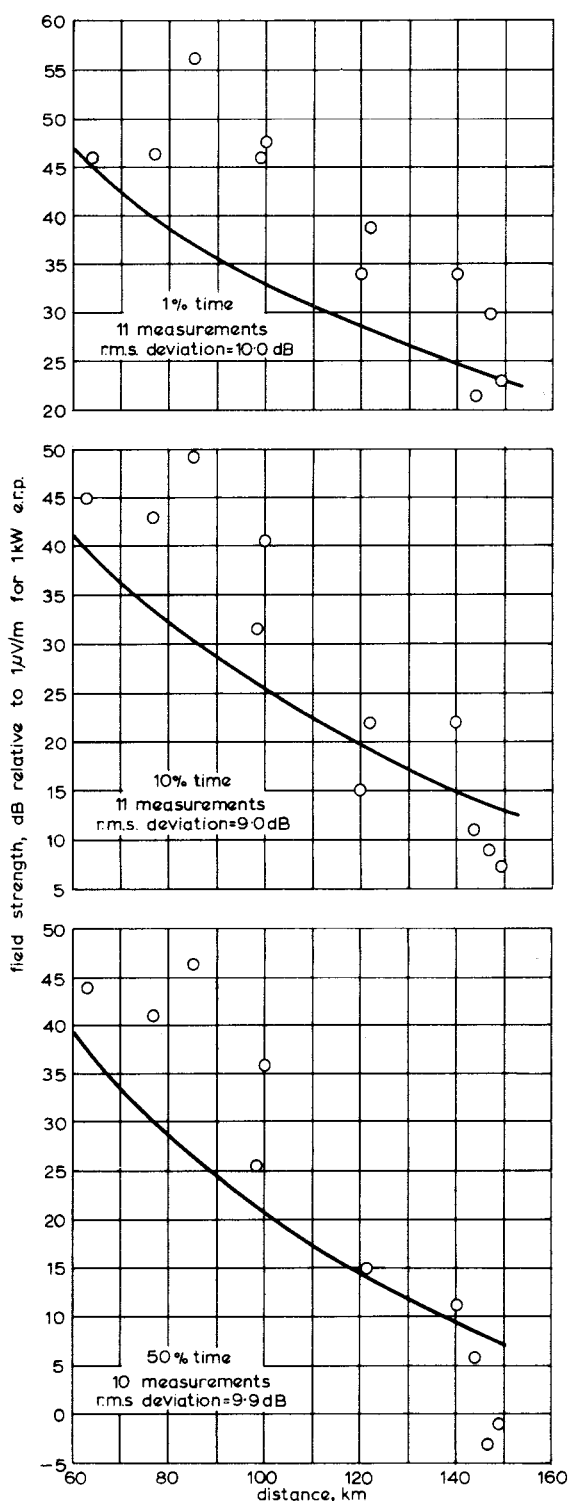


Fig. 6 - Comparison between measurements and CCIR predictions

Measurements corrected as in Table 4 (50% location and Δh corrections applied)

— CCIR curve for $h_t = 275$ m
 ○ measured results

It is apparent from Fig. 6 that the correlation between the normalized measurements and the CCIR curves is poor, with r.m.s. deviations of the order of 9 to 10 dB. In particular it appears that the slope of the CCIR curves is much less than indicated by the measurements over this range of distance and that the measurements at distances less than 100 km are substantially greater than the CCIR estimates for all time percentages. This discrepancy could be assumed to arise from an anomaly in the compilation of the CCIR curves. This anomaly results from the fact that at short ranges the curves are derived from measurements which were generally median values of town surveys; at longer ranges the receiving sites were generally (as in this series) in open country, and the results of the measurements then adjusted to be representative of typical receiving locations also in open country. Consequently the long range measurements do not make allowance for the effect of the additional losses in built-up areas (urban clutter loss) which are inherent in the short range results. Thus any smooth curve combining the two sets of results must, over the transitional region, have a lesser slope than would have resulted if both initial sets of data had been consistent in respect of urban clutter loss.

Fig. 7 also compares the measured results with the CCIR curves, but in this case no correction has been made to the measurements for terrain roughness (Δh correction). It will be seen that the omission of this correction has resulted in a significant improvement in the correlation for the 1% and 10% times, the r.m.s. deviations of measurements from the CCIR curves being less than 7 dB. The corresponding deviation for 50% time is 8 dB, representing also a small improvement in correlation relative to that with Δh correction applied.

6. COMPARISON BETWEEN MEASUREMENTS AND BBC PREDICTION METHOD

The method currently adopted by the BBC for co-channel interference calculations is to be described elsewhere.⁷ This method, which is designed for computer operation, has one particular advantage over the CCIR method, namely that since a receiving location correction is introduced as one of the parameters in the calculation, no subjective correction such as that from Fig. 4(c) (as discussed in Section 4.3. (iii)) is required. Since, however, predicted results obtained by the BBC method are applicable to particular, rather than average, receiving locations the graphical form of comparison between measurement and prediction as shown in Figs. 6 and 7 is not appropriate. Consequently the comparison between measurements and predictions are represented in Table 5, for time percentages of 1%, 5%* and 50%. The measured results are those of Table 3 except for local obstruction corrections (from Table 4) applied to the values of Caversham, Bawdsey and Peterborough.

* Prediction curves for the current BBC method are given for 5% time, rather than for 10% time as favoured by the CCIR. The 5% value is considered to be more relevant to u.h.f. planning for which the aim is to provide protection against interference for at least 95% time.

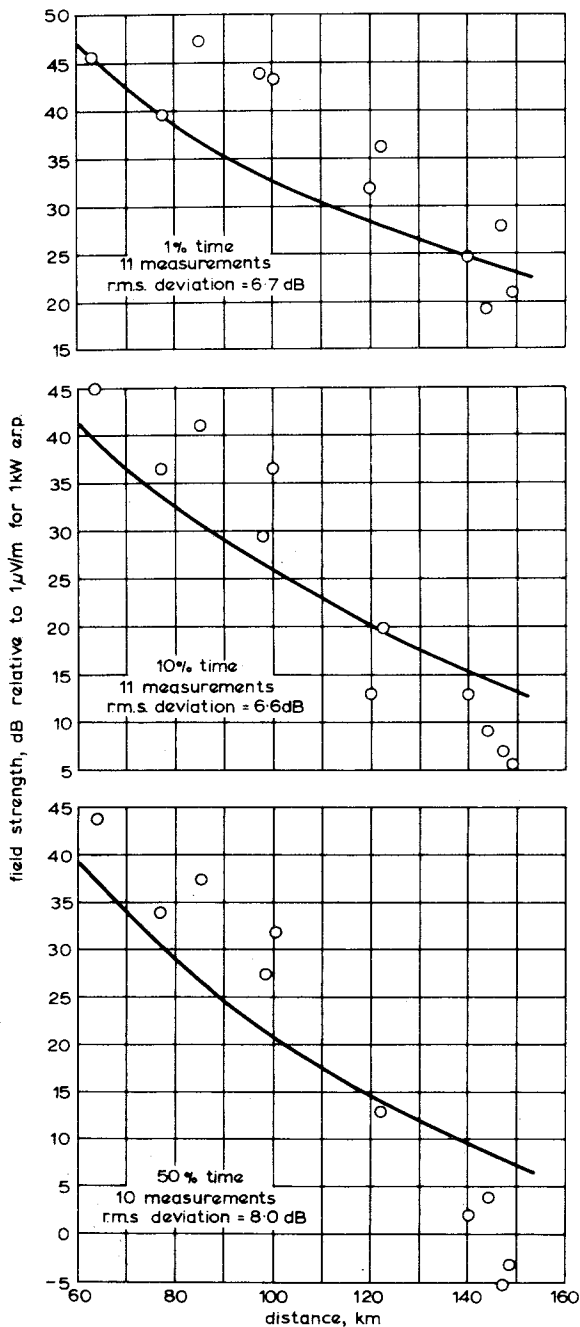


Fig. 7 - Comparison between measurements and CCIR predictions

Measurements corrected for 50% locations but not for Δh
— CCIR curve for $h_t = 275$ m
○ measured results

From Table 5 it may be seen that the r.m.s. deviations between measurement and prediction for 1% and 5% times are 7.1 dB and 6.8 dB respectively, indicating somewhat better agreement than was represented in Fig. 6 for the CCIR prediction method (albeit no better than for the CCIR method without Δh correction). The r.m.s. deviation for 50% time (7.9 dB) is somewhat less than for the CCIR method with Δh correction. There is also less evidence of any trend for deviation to vary with distance than in the comparisons of Figs. 6 and 7.

In passing it may be noted that the predicted fields exceeded for 5% and 50%* of the time over the Pontop Pike to Moorside Edge path are identical. The prediction programme yields this equality over any path for which the terminals are within the 'smooth-earth' horizon range of each other. For this particular path, although 140 km in length, this condition is realized on account of the high terminal heights involved. In practice, as shown in Fig. 2, the intervening terrain is mountainous and the path heavily diffracted. This results in a large discrepancy between the measured and predicted fields exceeded for 50% of the time. Such anomalies are inevitable over untypical paths in any prediction method which does not take account of the full path profile. It may be noted from Figs. 6 and 7 that this value (50% time at 140 km) is the only one for which significantly improved correlation between measurement and CCIR prediction is achieved by incorporation of the Δh correction to take account of the exceptional terrain irregularity.

7. EFFECT OF LOCAL TERRAIN UPON THE SIGNAL FADING RANGE

7.1. Results

In the BBC prediction method an important parameter in the calculation is the horizon elevation measured from the receiving point, and as discussed in Section 4.3 this parameter has been used to determine the location correction factors applied to the measurements in this report. It is implied that the correction factor is independent of propagation condition, i.e. of time-percentage, and consequently it is assumed that if, due to the nature of the local terrain, a location receives a particular degree of protection from interfering transmissions, this protection is maintained under all propagation conditions. An investigation to test the validity of this assumption has previously been carried out on Band I⁹ and it was concluded that:— 'an improvement in protection is obtained when receiving locations are screened from long distance interference by hills. This is maintained during both normal and abnormal propagation conditions, with a slight tendency to increase in the latter case'.

It was desired to investigate whether this conclusion was also valid at u.h.f., and it was for this reason that the reception measurements of Sutton Coldfield were carried out at Brookmans Park and Hatfield, two receiving sites within 5 km of each other. Examination of the relevant path profiles of Fig. 2 shows these to be similar except at the receiving end. Due to the greater height of the Brookmans Park site the radio horizon, (for 4/3 earth's radius), is some 27 km from the receiving terminal, whereas from Hatfield the horizon occurs at less than 7 km. The respective horizon elevation angles, taking earth's curvature into account are 0° and 0.35° respectively.

* The range of fading between time percentages of 5% and 50% is of importance in the BBC prediction method, in which account is taken of the increased subjective effect of continuous interference. Over paths within the smooth-earth horizon range 10 dB is added to the predicted field strength exceeded for 5% time.

TABLE 5

Comparison Between Measurements and Results of BBC Prediction Method

Transmission Path	Field strengths exceeded for specified time percentages dB(μV/m) for 1 kW e.r.p.								
	1%			5%			50%		
	M	P	D	M	P	D	M	P	D
Crystal Palace to Caversham	58.0	58.0	0	57.5	55.5	- 2.0	56.0	54.5	-1.5
Crystal Palace to Mursley	50.5	52.4	+ 1.9	47.5	48.2	+ 0.7	45.0	48.2	+ 3.2
Pontop Pike to Dishforth	56.5	54.6	- 1.9	52.0	50.1	- 1.9	46.5	50.1	+ 3.6
Crystal Palace to Manningtree	53.0	42.0	+11.0	42.0	36.5	- 5.5	32.5	22.4	-10.1
Sutton Coldfield to Mursley	56.5	47.3	- 9.2	51.0	42.4	- 8.6	45.0	42.4	- 2.6
Crystal Palace to Bawdsey	38.0	29.0	- 9.0	24.5	20.0	- 4.5	No measured result		
Crystal Palace to Peterborough	41.5	37.0	- 4.5	30.5	30.5	0	18.0	8.1	- 9.9
Pontop Pike to Moorside Edge	27.0	28.5	+ 1.5	18.0	22.9	+ 4.9	4.5	22.9	+18.4
Sutton Coldfield to Hatfield	19.5	30.9	+11.4	11.0	23.2	+12.2	4.0	1.2	- 2.8
Crystal Palace to Tacolneston	38.0	33.8	- 4.2	23.5	26.3	+ 2.8	5.0	6.0	+ 1.0
Sutton Coldfield to Brookmans Park	29.0	38.4	+ 9.4	17.5	31.7	+14.2	5.0	12.1	+ 7.1
r.m.s. deviation (dB)			7.1	6.8			7.9		

Column M corresponds to the measured results

Column P corresponds to the predicted results

Column D corresponds to the discrepancy between measurement and prediction expressed as the ratio P : M (dB)

The field strength/time-percentage distributions resulting from the measurements at the two sites have already been shown in Fig. 3(b), from which it may be seen that whilst both have virtually the same median value the slope of the distribution at Brookmans Park is greater. As a consequence of this greater gradient the field strengths exceeded for 10% and 1% times at Brookmans Park are greater than those for corresponding time percentages at Hatfield by 4½ dB and 9½ dB respectively. Results of this nature were implied in the conclusion of the previous report,⁹ which stated that terrain protection shows a tendency to increase under conditions of abnormal propagation.

The results obtained at Tacolneston afford an interesting comparison with those of Brookmans Park and Hatfield. All three paths are similar in length but the Tacolneston path is the least obstructed, (see Fig. 2), with a radio horizon some 50 km from the receiving site, corresponding to an elevation angle of -0.1° i.e. the horizon is below the horizontal plane. As might be expected from the comparisons discussed in the previous paragraphs, the Tacolneston field strength/time-percentage curve (curve vi of Fig. 3(a)) is even steeper than that of Brookmans Park (Fig. 3(b)), field strengths being 11.5 dB greater at 0.1% time and only 3.5 dB greater at 10% time.

7.2. Discussion of Results

Abnormal tropospheric propagation results from corresponding abnormalities in the refractive index gradient of the atmosphere. Since the effective earth curvature factor (*k*) is a function of this refractive index gradient, the concept of variation of the effective earth's radius according to atmospheric conditions is an accepted artifice in radio meteorology. In order to show the effect of this variation of effective earth's radius over the measured paths, the ray

path corresponding to flat earth (*k* = ∞) is superimposed on the profiles of Fig. 2. For this condition the Tacolneston path is completely unobstructed, that to Brookmans Park has a point of grazing incidence at approximately 25 km from the receiving terminal, and that to Hatfield is still obstructed at several points. As discussed in Appendix II considerations of simple Fresnel knife-edge theory show that the reduction of diffraction loss due to increase of effective earth's radius will be greatest for small initial values of obstacle height. Consequently although the measurements show that the condition of *k* = ∞ is not realized in practice* it may be expected that increase of earth's radius will result in a greater reduction of diffraction loss over the lesser obstacle heights of the Crystal Palace to Tacolneston profile than over the Sutton Coldfield to Brookmans Park profile; this in turn will show a greater reduction than the Sutton Coldfield to Hatfield path. This expectation appears to be substantiated by the measured results, albeit it will be appreciated that the concept of a uniformly variable effective earth's curvature affords only a simplified representation of the many different and often complex modes of propagation modes occurring in practice.

A comparison between the fading ranges of the measurements and of the CCIR predictions is given in Table 6. This shows the average slope of the field-strength/time-percentage distributions between 1% and 50% of the time, as measured at Tacolneston and Brookmans Park, to be appreciably greater than indicated by the CCIR prediction. The corresponding slope resulting from the Hatfield measurements is however in good agreement with the prediction. This is gratifying in that the location correction of Table 4 shows Hatfield to represent an average receiving location.

* The maximum field strength received at Tacolneston is approximately 6 dB less than the free space value.

TABLE 6
Comparison Between Measured and Predicted Signal Fading Ranges

Path	Path Length (km)	Ratio (dB) between field strength exceeded for specified time percentage		
		1% – 50%	10% – 50%	1% – 10%
Sutton Coldfield to Hatfield	144	15.5	5.0	10.5
Sutton Coldfield to Brookmans Park	149	24	8.5	15.5
Crystal Palace to Tacolneston	147	33	12	21
CCIR (ht. 275 m)	145	15.5	5.5	10

Since the results show the range of fading at a given distance to depend upon the nature of the receiving location, two conclusions may be drawn from the comparison between measurements, CCIR curves, and the BBC prediction method:—

- (i) It cannot be assumed that any results obtained at a particular receiving location can be normalized to correspond to the values at a median (50%) location by means of a single correction factor applicable to all time percentages. For example, as may be seen from Table 4, this assumption has resulted in the amended values of field strength exceeded for 50% time at Tacolneston and Brookmans Park being substantially lower than the value for Hatfield, although the measurements themselves, (Table 3), show all these values to be virtually identical. In other words the only simple means of relating measurements to the CCIR curves for 50% locations is to ensure that the measurements are in fact made at average receiving locations.
- (ii) Modifications to any prediction method to relate the range of fading to factors other than path length and terminal heights would seem to require more detailed consideration of the whole path profile. Although the CCIR method attempts to do this by means of the Δh correction application of this parameter appears, as discussed previously, to generally worsen the correlation between measurement and prediction. Substantially more measurement data over differing types of terrain would seem to be required to justify any modification of the existing BBC prediction method.

8. CONCLUSIONS

The measurements described in this report provide a useful additional contribution to the data available for planning purposes at u.h.f. over the important range of path lengths from 60 km to 150 km. From these results the following conclusions may be drawn:—

- (i) Comparisons between the measurements and the CCIR curves of Rec. 370-1 show that the rate of decrease of field strength with increasing distance of these curves is less than indicated by the measurements at all time percentages. The correlation between measurements and the CCIR curves is improved if the correction for terrain roughness (Δh) is neglected.
- (ii) Comparisons between these measurements and the results obtained by the BBC prediction method indicate a degree of correlation at least as good as that of the CCIR method. To some extent an improved correlation is to be expected for the BBC prediction method since all the data detailed in this report were incorporated in the optimization of parameters, whereas only that detailed in Fig. 3(c) has been used in the derivation of the CCIR curves.

- (iii) Comparisons between the results obtained over three transmission paths of similar lengths show substantial differences in fading ranges. These differences must be attributed to the differing path profiles, and in particular to the nature of this profile in the vicinity of the receiving terminal. It seems probable that the fading range will be a maximum when small angles of diffraction are involved. The principal implication is that no single value of correction factor can be applied to relate median location field strengths to those at particular locations, since the required correction may vary with percentage time. A suitable amendment allowing for this effect could be incorporated more easily into the BBC prediction method than into the CCIR method in view of the highly subjective assessment regarding 'location percentage' required by the latter method. Any significant improvement in prediction techniques is likely to require fuller consideration of individual path profiles. At present, for computer prediction, this has not been considered practicable in view of the substantial data storage problems involved and of the sparsity of measurement data required for optimization of the increased number of parameters.

- (iv) These comparative measurements confirm the conclusions of a previous report, namely that the improvement in protection obtained when receiving locations are screened from long-distance interference by hills, shows a tendency to increase during abnormal propagation conditions. Care should however be taken in interpreting this statement since it must be remembered that the usual standard of reference is the median (50%) location which itself will in general be screened to some extent by hills. It is therefore more appropriate to say that the reduction in protection due to the loss of the screening effect of hills at exposed receiving locations shows a tendency to be more pronounced under conditions of abnormal propagation.

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- (iii) The Buckinghamshire County Constabulary

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A.1.1. General

This report has described a series of long-term u.h.f. field strength measurements carried out over a number of overland transmission paths ranging in distance from 60 to 150 km in length. Their purpose was to provide further statistical data required for planning purposes in this broadcast band. The planning of the u.h.f. broadcasting network in the U.K. has now reached the stage at which a computer programme is used to assess the expected levels of co-channel interference (cci) due to approximately 200 main stations and 150 relay stations operating in this Band. It therefore seemed appropriate to analyse the computed data to determine the statistical distribution (with respect to path length) of significant sources of interference, and thereby to assess whether the most important types and lengths of transmission path are suitably represented in the available measurement data.

The computer output data provide predictions of the field strength required to protect a service from cci for 95% of the time at each of more than 2000 test locations representatively sited in the service areas of existing and proposed main and relay station service areas in the U.K. In computing the protected field strength appropriate allowance (as recommended by the CCIR) is made for interfering station radiated power, frequency offset, polarization, and receiving aerial directivity. For the purpose of this analysis the minimum field strength protected against the principal* source of cci at each test location was noted; also noted were the nature** and length of the transmission path linking test location and interfering source. The results of this analysis are presented in histogram form in Figs. 8 and 9 relating, respectively, to test locations in service areas of main and of relay stations. Fig. 10 represents a comparable analysis of 463 locations selected as possible sites for 're-broadcast reception' (r.b.r.). In this instance the criterion is that the wanted signal should be protected from cci for at least 99% of the time.

A.1.2. Comment

From the analyses*** presented in Figs. 8, 9 and 10 the following may be deduced:—

- (i) CCI levels in main station service areas tend to be substantially lower than in relay station service areas. It is generally accepted that, whereas the planning aim is to protect all locations receiving fields of 70 dB(μ V/m) and above, it may not be practicable to protect fields of less than 80 dB(μ V/m) in many relay station service areas.

* Here arbitrarily defined as the source providing the greatest field strength exceeded for 5% of the time.

** 'Mixed' paths here defined as those not exceeding 90% overland or 90% oversea.

*** These analyses consider only the predominant source of interference. At many locations the degree of protection may be poorer than indicated since more than one source contributes to the interference.

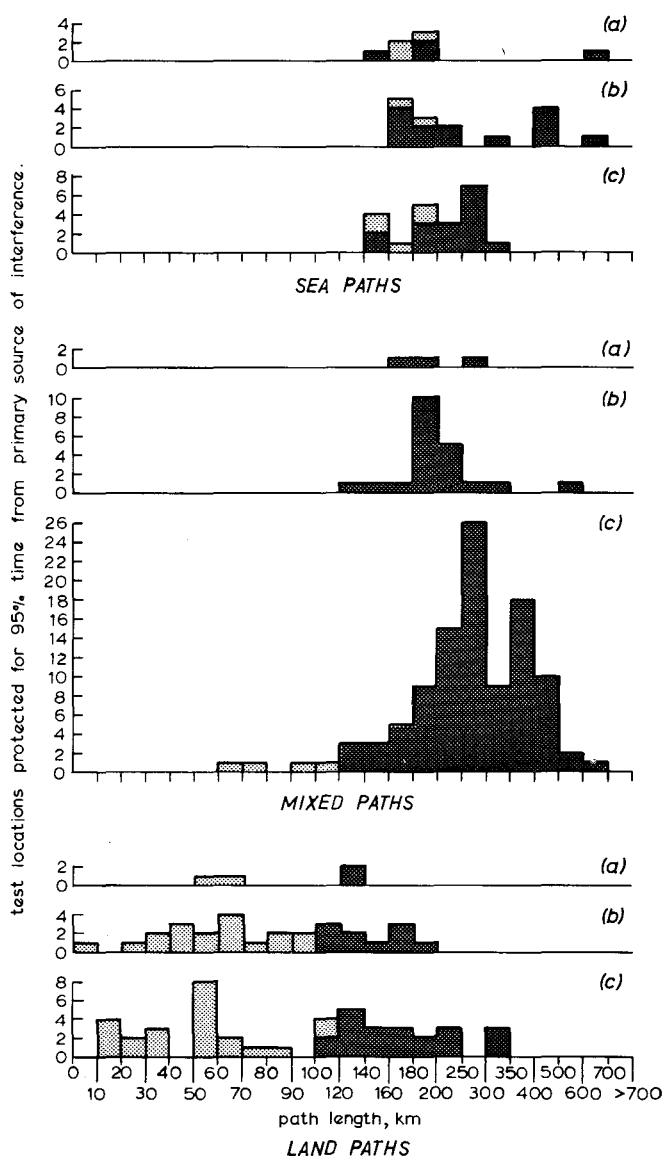


Fig. 8 - Analysis of co-channel interference levels at test locations of main stations

- (a) Protected field strength exceeds 70 dB(μ V/m)
 - (b) Protected field strength within range 60–70 dB(μ V/m)
 - (c) Protected field strength within the range 50–60 dB(μ V/m)
- 1066 locations analysed

■ Principal interfering source is a main station
 ▨ Principal interfering source is a relay station

- (ii) The only significant sources of interference situated less than 100 km from main station test locations are relay stations, and involve overland transmission paths. Short range interference to locations in relay station service areas is caused primarily by other relay stations. Relay station test locations suffering interference from main stations are in general between 40 and 180 km from the interfering source.
- (iii) No significant interference is predicted to occur in either main or relay station service areas from

sources over 200 km distant provided the transmission path is overland (only 1 sample exceeds 180 km). Significant interference from sources at greater distances is due to propagation over sea or mixed land/sea paths.

(iv) As would be expected, Fig.10 shows that at r.b.r. test locations (requiring protection for 99% of the time and using more highly directional receiving aerals) the sources of interference tend to be at greater distances than for service area locations.

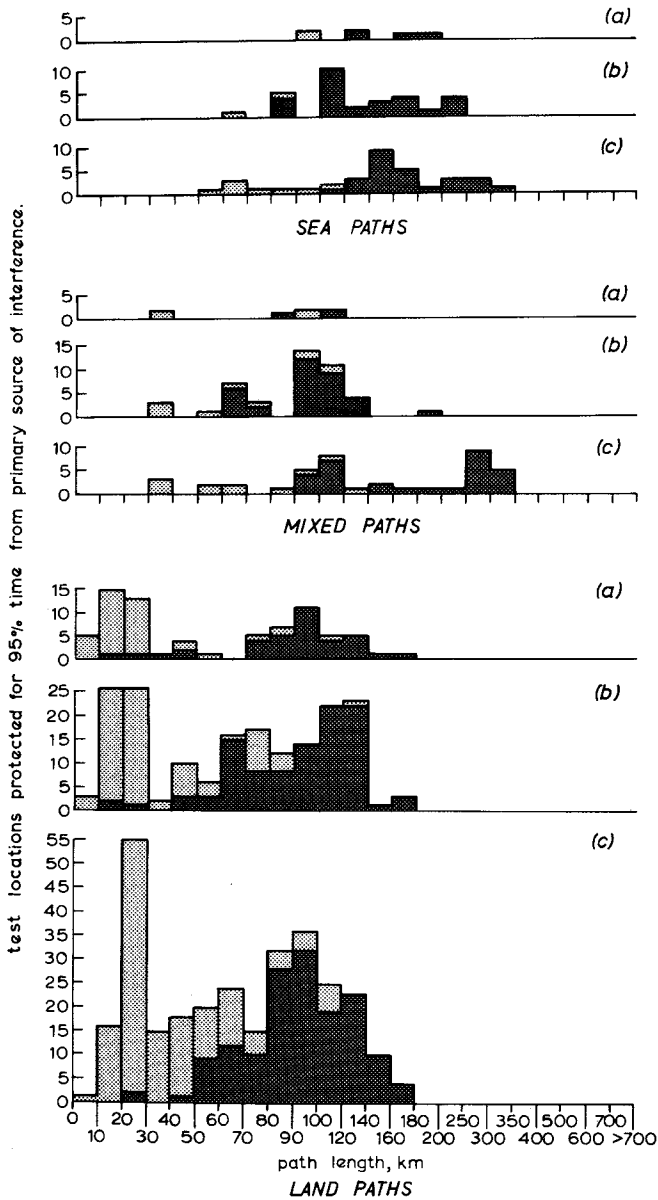


Fig. 9 - Analysis of co-channel interference levels at test locations of relay stations
(a) Protected field strength exceeds 90 dB(μV/m)
(b) Protected field strength within the range 80–90 dB(μV/m)
(c) Protected field strength within the range 70–80 dB(μV/m)
1072 Locations analysed

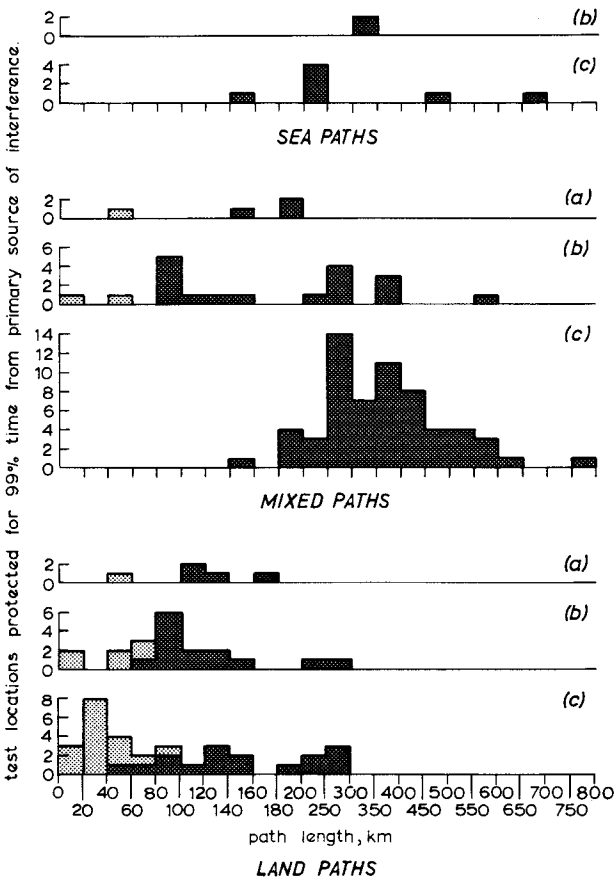


Fig. 10 - Analysis of co-channel interference levels at r.b.r. site test locations
(a) Protected field strength exceeds 90 dB(μV/m)
(b) Protected field strength within the range 80–90 dB(μV/m)
(c) Protected field strength within the range 70–80 dB(μV/m)
463 Locations analysed

Principal interfering source is a main station
Principal interfering source is a relay station

A.1.3. Conclusions

Whilst it is inevitable from the geography of the U.K. that cci due to sources at considerable distances from the receiving point should involve overseas or mixed land/sea transmission paths, it would appear that overland paths exceeding 180 km are of minor significance in u.h.f. planning.

The medium distance measurements described in this report provide a useful addition to the available measurement data, covering an important range of path length. Assessments of short range interference between adjacent relay stations and involving no fading of the interfering signal may, if required, be treated by conventional 'service area' prediction techniques. There remains a lack of measurement data over land paths between 50 and 100 km in length and involving low transmitting aerial heights typical of relay stations. Fading over such paths may be somewhat greater than indicated by the results over comparable distances detailed in this report.

APPENDIX II

Reduction of Diffraction Loss due to Change of Effective Earth's Radius

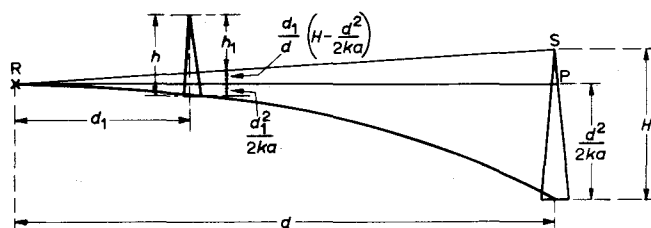


Fig. 11 - Geometry for diffraction over curved earth

Earth radius = a
Curvature factor = k

Fig. 11 shows a receiving point R, obstructed from a source S, by an obstacle of height h at distance d_1 from R. The source, which may be either the transmitter or another diffraction edge is at distance d from R and of height H . For convenience both h and H are specified relative to the height above ground level of point R, and the line RP represents the horizontal through R.

The effective obstacle height h_1 , for earth curvature factor k_0 is given by

$$h_1 = h - \left[\frac{d_1^2}{2k_0 a} + \frac{d_1}{d} \left(H - \frac{d^2}{2k_0 a} \right) \right]$$

and the effective height h_1' for earth curvature factor k' by:—

$$h_1' = h - \left[\frac{d_1^2}{2k' a} + \frac{d_1}{d} \left(H - \frac{d^2}{2k' a} \right) \right]$$

Whence the effective reduction in obstacle height due to increase of curvature factor is given by:—

$$h_1 - h_1' = \frac{d_1^2}{2k_0 a} \left[\left(\frac{k_0}{k'} - 1 \right) + \frac{d}{d_1} \left(1 - \frac{k_0}{k'} \right) \right] = \frac{K d_1^2}{2k_0 a}$$

Where

$$K = \left(\frac{k_0}{k'} - 1 \right) + \frac{d}{d_1} \left(1 - \frac{k_0}{k'} \right) = \left(1 - \frac{k_0}{k'} \right) \left(\frac{d}{d_1} - 1 \right)$$

Table A gives the appropriate values of $h_1 - h_1'$ for various ratios of d/d_1 and k'/k_0 assuming $k_0 = 4/3$ and $a = 6350$ km.

TABLE A

$\frac{d}{d_1}$	$\frac{k'}{k_0}$	K	$h_1 - h_1'$ (m)		
			$d_1 = 2$ km	$d_1 = 5$ km	$d_1 = 10$ km
5	2	2	0.5	3	12
	4	3	0.66	4.4	17.5
	8	3.5	0.8	5.1	20.6
10	2	4.5	1	6.6	26.5
	4	6.75	1.6	10	40
	8	7.9	1.85	12	46

This table shows that the change in effective obstacle height with variation of k is likely to be of significance only if $d_1 \leq 5$ km.

Table B relates the reduction in diffraction loss (Fresnel knife-edge theory for $d_1 \ll d$ and frequency = 600 MHz) due to reduction in effective obstacle height ($h_1 - h_1'$) for various values of initial effective obstacle height (h_1).

TABLE B

h_1 (m)	Reduction in Diffraction Loss (dB)		
	$h_1 - h_1'$		$h_1 - h_1'$
	50 m	25 m	25 m
	for $d_1 = 10$ km		$d_1 = 5$ km
0	7	4½	5½
50	7½	4	5
100	6	3	3
150	4	2	2
200	2	1	1

From Table B it may be seen that the reduction in diffraction loss due to increase of effective earth radius is a maximum when the effective height h_1 is small.